Chair of Metal Forming and Casting
TUM School of Engineering and Design
Technical University of Munich

Development of a physical geometry analysis for process-oriented topology optimization

Final Report

Motivation

Topology-optimized components offer the advantage of reducing component weight while maintaining high rigidity and high component strength. However, latest optimization software currently only takes the casting process into account through basic manufacturing restrictions, such as minimum wall thicknesses, avoidance of undercuts or draft angles.

Proceed

This project investigated the development of data-driven models that allow the casting process for any geometry to be evaluated without having to carry out complex simulations. For this purpose, suitable models were developed for mold filling in high pressure die casting and for solidification in gravity-driven casting processes. These models were examined with regard to their prediction accuracy, model limits and required computational effort. The models were validated by experiments on a hpdc machine and gravity-driven tests with 3D-printed sand molds.

Results and Outlook

For gravity-driven processes, a surrogate model was developed based on the medial axis transformation. This model uses the triangulated component surface as the basis for identifying material accumulations in the component. Automated adjustment of the geometry reduces defects caused by shrinkage cavities. It was shown that a robust and reproducible determination of the medial axis is possible with this procedure for any geometry and even with noisy surfaces. The results were published in [1].

The determination of the solidification time in the medial axis model is based on the local cross-section of a component. In order to enable the solidification time for complex geometries, a data-driven substitute model was developed. This model, which is trained on existing simulation results, enables the local assessment of the solidification time without having to carry out meshing or simulation [2]. It was validated by measuring the solidification time in casting experiments with 3D-printed sand molds.

The combination of the metamodel with the topology optimization showed that a one-time process validation at the end of the optimization process with adapted post-processing leads to better results for both gravity-driven and impulse-driven processes. This applies in particular to manufacturability and volume-related stiffness [3].

Publications

- [1] https://doi.org/10.1016/j.cad.2022.103394
- [2] https://doi.org/10.1088/1757-899X/1281/1/012037
- [3] https://doi.org/10.3390/ma14133715
- [4] https://doi.org/10.1016/j.procir.2023.06.189

Project run time

07/2020 to 06/2023

Funding

DFG - 434348474

Partnerships

Chair for Engineering Design and CAD, University of Bayreuth

Research done by
Maxiilian Erber